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OBSERVATIONS  
ON  
SMOKY CHIMNEYS,  
THEIR  
CAUSES AND CURE;  
WITH  
CONSIDERATIONS ON FUEL AND STOVES.

Illustrated with PROPER FIGURES.

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BY  
BENJAMIN FRANKLIN, LL. D.

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## A D V E R T I S E M E N T.

**T**O any work on Philosophy which bears the name of BENJAMIN FRANKLIN, eulogium is unnecessary. It will suffice therefore to say, the following sheets were penned by that great Philosopher, and make part of the published Transactions of the American Philosophical Society.

The subject is one which claims particular attention in England, where, from the accustomed mode of warming rooms, smoke is liable to be very obnoxious to persons, and detrimental to furniture. The means to preserve the one, and to augment the comforts of the other, are clearly pointed out in the following Essay, which may be considered as divided into two parts: the first contains an enquiry into the causes of smoky chimneys; the second points out the remedies. To spread therefore the knowledge which these sheets contain, will it is hoped be considered as rendering a service to the community in general.

To these reasonings on the causes and cure of smoky chimneys are subjoined, by the same able hand, considerations and experiments on stoves or fire-places; in which will be found many valuable observations and hints for the œconomical management of fuel; an article in general costly, but particularly so in this metropolis.

LONDON, 1793.



## O B S E R V A T I O N S

O N

## S M O K Y C H I M N E Y S.

*A Letter from Dr. B. FRANKLIN to Dr. INGENHAUSZ, Physician to the Emperor, at Vienna.*

At Sea, August 28th, 1785.

Dear Friend,

**I**N one of your letters, a little before I left France, you desire me to give you in writing my thoughts upon the construction and use of chimneys, a subject you had sometimes heard me touch upon in conversation. I embrace willingly this leisure afforded by my present situation to comply with your request, as it will not only shew my regard to the desires of a friend, but may at the same time be of some utility to others, the doctrine of chimneys appearing not to be as yet generally well

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understood, and mistakes respecting them being attended with constant inconvenience, if not remedied, and with fruitless expence, if the true remedies are mistaken.

Those who would be acquainted with this subject should begin by considering on what principle smoke ascends in any chimney. At first many are apt to think, that smoke is in its nature and of itself specifically lighter than air, and rises in it for the same reason that cork rises in water. These see no cause why smoke should not rise in the chimney, though the room be ever so close. Others think there is a power in chimneys to *draw* up the smoke, and that there are different forms of chimneys which afford more or less of this power. These amuse themselves with searching for the best form. The equal dimensions of a funnel in its whole length is not thought artificial enough; and it is made, for fancied reasons, sometimes tapering and narrowing from below upwards, and sometimes the contrary, &c. &c. A simple experiment or two may serve to give more correct ideas. Having lit a pipe of tobacco, plunge the stem to the bottom of a decanter half filled with cold water; then putting a rag over the bowl, blow through it, and make the smoke descend in the stem of the pipe, from the end of which it will rise in bubbles through the water; and being thus cooled, will not afterwards rise to go out through the neck of the decanter, but remain spreading itself and resting

ing on the surface of the water. This shows that smoke is really heavier than air, and that it is carried upwards only when attached to, or acted upon by air that is heated, and thereby rarefied and rendered specifically lighter than the air in its neighbourhood.

Smoke being rarely seen but in company with heated air, and its upward motion being visible, though that of the rarefied air that drives it is not so, has naturally given rise to the error.

I need not explain to you, my learned friend, what is meant by rarefied air; but if you make the public use you propose of this letter, it may fall into the hands of some who are unacquainted with the term and with the thing. These then may be told, that air is a fluid which has weight as well as others, though about eight hundred times lighter than water. That heat makes the particles of air recede from each other and take up more space, so that the same weight of air heated will have more bulk than equal weights of cold air which may surround it, and in that case must rise, being forced upwards by such colder and heavier air, which presses to get under it and take its place. That air is so rarefied or expanded by heat, may be proved to their comprehension by a lank-blown bladder, which laid before a fire will soon swell, grow tight, and burst.

Another experiment may be to take a glass  
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tube

tube about an inch in diameter, and twelve inches long, open at both ends, and fixed upright on legs so that it need not be handled, for the hands might warm it. At the end of a quill fasten five or six inches of the finest light filament of silk, so that it may be held either above the upper end of the tube, or under the lower end, your warm hand being at a distance by the length of the quill. If there were any motion of air through the tube, it would manifest itself by its effect on the silk\*; but if the tube and the air in it are of the same temperature with the surrounding air, there will be no such motion, whatever may be the form of the tube, whether crooked or straight, narrow below and winding upwards, or the contrary; the air in it will be quiescent. Warm the tube, and you will find, as long as it continues warm, a constant current of air entering below and passing up through it, till discharged at the top; because the warmth of the tube being communicated to the air it contains, rarefies that air, and makes it lighter than the air without, which therefore presses in below, forces it upwards, follows and takes its place, and is rarefied in its turn. And, without warming the tube, if you hold under it a knob of hot iron, the air thereby heated will rise and fill the tube, going out at its top; and this motion in the tube will continue as long

\* Plate I. Fig. 1.

as the knob remains hot, because the air entering the tube below is heated and rarefied by passing near and over that knob.

That this motion is produced merely by the difference of specific gravity between the fluid within and that without the tube, and not by any fancied form of the tube itself, may appear by plunging it into water contained in a glass jar a foot deep, through which such motion might be seen. The water within and without the tube being of the same specific gravity, balance each other, and both remain at rest. But take out the tube, stop its bottom with a finger, and fill it with olive oil, which is lighter than water, then stopping the top, place it as before, its lower end under water, its top a very little above. As long as you keep the bottom stoppt, the fluids remain at rest; but the moment it is unstoppt, the heavier enters below, forces up the lighter, and takes its place. And the motion then ceases, merely because the new fluid cannot be successively made lighter, as air may be by a warm tube.

In fact, no form of the funnel of a chimney has any share in its operation or effect respecting smoke, except its height. The longer the funnel, if erect, the greater its force, when filled with heated and rarefied air, to *draw* in below and drive up the smoke, if one may, in compliance with custom, use the expression *draw*, when in fact it is the superior weight of



the surrounding atmosphere that *presses* to enter the funnel below, and so *drives up* before it the smoke and warm air it meets with in its passage.

I have been the more particular in explaining these first principles, because, for want of clear ideas respecting them, much fruitless expence has been occasioned; not only single chimneys, but, in some instances within my knowledge, whole stacks having been pulled down, and rebuilt with funnels of different forms, imagined more powerful in *drawing* smoke; but, having still the same height and the same opening below, have performed no better than their predecessors.

What is it then which makes a *smoky chimney*; that is, a chimney which, instead of conveying up all the smoke, discharges a part of it into the room, offending the eyes, and damaging the furniture?

The causes of this effect, which have fallen under my observation, amount to *nine*, differing from each other, and therefore requiring different remedies.

1. *Smoky chimneys, in a new house, are such frequently from mere want of air.* The workmanship of the rooms being all good, and just out of the workman's hand, the joints of the boards of the flooring, and of the pannels of wainscoting, are all true and tight, the more so as the walls, perhaps not yet thoroughly dry, preserve a dampness in the air of the room  
which



which keeps the wood-work swelled and close. The doors and the sashes too, being worked with truth, shut with exactness, so that the room is as tight as a snuff-box, no passage being left open for air to enter, except the key-hole, and even that is sometimes covered by a little dropping shutter. Now, if smoke cannot rise but as connected with rarefied air, and a column of such air, suppose it filling the funnel, cannot rise, unless other air be admitted to supply its place; and if, 'therefore, no current of air enter the opening of the chimney, there is nothing to prevent the smoke coming out into the room. If the motion upwards of the air in a chimney that is freely supplied, be observed by the rising of the smoke, or a feather in it, and it be considered that in the time such feather takes in rising from the fire to the top of a chimney, a column of air equal to the content of the funnel must be discharged, and an equal quantity supplied from the room below, it will appear absolutely impossible that this operation should go on if the tight room is kept shut; for were there any force capable of drawing constantly so much air out of it, it must soon be exhausted like the receiver of an air-pump, and no animal could live in it. Those therefore who stop every crevice in a room to prevent the admission of fresh air, and yet would have their chimney carry up the smoke, require inconsistencies, and expect impossibilities. Yet, under this situation, I have

seen the owner of a new house, in despair, and ready to sell it for much less than it cost, conceiving it uninhabitable, because not a chimney in any one of its rooms would carry off the smoke, unless a door or window were left open. Much expence has also been made, to alter and amend new chimneys which had really no fault; in one house particularly that I knew, of a nobleman in Westminster, that expence amounted to no less than three hundred pounds, *after* his house had been, as he thought, finished, and all charges paid. And, after all, several of the alterations were ineffectual, for want of understanding the true principles.

*Remedies.* When you find, on trial, that opening the door or a window enables the chimney to carry up all the smoke, you may be sure that want of air *from without* was the cause of its smoking: I say *from without*, to guard you against a common mistake of those who may tell you, the room is large, contains abundance of air, sufficient to supply any chimney, and therefore it cannot be that the chimney wants air. These reasoners are ignorant, that the largeness of a room, if tight, is in this case of small importance, since it cannot part with a chimney full of its air without occasioning so much vacuum; which it requires a great force to effect, and could not be borne if effected.

It appearing plainly, then, that some of the outward air must be admitted, the question will

will be, how much is *absolutely necessary*? for you would avoid admitting more, as being contrary to one of your intentions in having a fire, viz. that of warming your room. To discover this quantity, shut the door gradually while a middling fire is burning, till you find that, before it is quite shut, the smoke begins to come out into the room; then open it a little, till you perceive the smoke comes out no longer. There hold the door, and observe the width of the open crevice between the edge of the door and the rabbit it should shut into. Suppose the distance to be half an inch, and the door eight feet high, you find thence that your room requires an entrance for air equal in area to ninety-six half inches, or forty-eight square inches, or a passage of six inches by eight. This however is a large supposition, there being few chimneys that, having a moderate opening and a tolerable height of funnel, will not be satisfied with such a crevice of a quarter of an inch; and I have found a square of six by six, or thirty-six square inches, to be a pretty good medium, that will serve for most chimneys. High funnels, with small and low openings, may indeed be supplied through a less space, because, for reasons that will appear hereafter, the *force of levity*, if one may so speak, being greater in such funnels, the cool air enters the room with greater velocity, and consequently more enters in the same time. This however has its limits; for  
experience

experience shews, that no increased velocity so occasioned, has made the admission of air through the key-hole equal in quantity to that through an open door, though through the door the current moves slowly, and through the key-hole with great rapidity.

It remains then to be considered how and where this necessary quantity of air from without is to be admitted so as to be least inconvenient. For if at the door left so much open, the air thence proceeds directly to the chimney, and in its way comes cold to your back and heels as you sit before your fire. If you keep the door shut, and raise a little the sash of your window, you feel the same inconvenience. Various have been the contrivances to avoid this; such as bringing in fresh air through pipes in the jams of the chimney, which pointing upwards should blow the smoke up the funnel; opening passages into the funnel above, to let in air for the same purpose. But these produce an effect contrary to that intended: for as it is the constant current of air passing from the room *through the opening of the chimney* into the funnel, which prevents the smoke coming out into the room, if you supply the funnel by other means or in other ways with the air it wants, and especially if that air be cold, you diminish the force of that current, and the smoke, in its efforts to enter the room, finds less resistance.

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The wanted air must then *indispensably* be admitted into the room, to supply what goes off through the opening of the chimney. M. Gauger, a very ingenious and intelligent French writer on the subject, proposes with judgment to admit it *above* the opening of the chimney; and to prevent inconvenience from its coldness, he directs its being made to pass in its entrance through winding cavities made behind the iron back and sides of the fire-place; and under the iron hearth-plate; in which cavities it will be warmed, and even heated, so as to contribute much, instead of cooling, to the warming of the room. This invention is excellent in itself, and may be used with advantage in building new houses; because the chimneys may then be so disposed, as to admit conveniently the cold air to enter such passages: but in houses built without such views, the chimneys are often so situated, as not to afford that convenience without great and expensive alterations. Easy and cheap methods, though not quite so perfect in themselves, are of more general utility; and such are the following.

In all rooms where there is a fire, the body of air warmed and rarefied before the chimney is continually changing place, and making room for other air that is to be warmed in its turn. Part of it enters and goes up the chimney, and the rest rises and takes place near the ceiling.



ceiling. If the room be lofty, that warm air remains above our heads as long as it continues warm, and we are little benefited by it, because it does not descend till it is cooler. Few can imagine the difference of climate between the upper and lower parts of such a room, who have not tried it by the thermometer, or by going up a ladder till their heads are near the ceiling. It is then among this warm air that the wanted quantity of outward air is best admitted, with which being mixed, its coldness is abated, and its inconvenience diminished, so as to become scarce observable. This may be easily done, by drawing down about an inch the upper sash of a window; or, if not moveable, by cutting such a crevice through its frame; in both which cases, it will be well to place a thin shelf of the length, to conceal the opening, and sloping upwards to direct the entering air horizontally along and under the ceiling. In some houses the air may be admitted by such a crevice made in the wainscot, cornice, or plastering, near the ceiling, and over the opening of the chimney. This, if practicable, is to be chosen, because the entering cold air will there meet with the warmest rising air from before the fire, and be soonest tempered by the mixture: the same kind of shelf should also be placed here. Another way, and not a very difficult one, is to take out an upper pane of glass in one of your sashes,



fasthes, set it in a tin frame, giving it two springing angular sides, and then replacing it, with hinges below on which it may be turned to open more or less above\*. It will then have the appearance of an internal sky-light. By drawing this pane in, more or less, you may admit what air you find necessary. Its position will naturally throw that air up and along the ceiling. This is what is called in France a *Was ist das?* As this is a German question, the invention is probably of that nation, and takes its name from the frequent asking of that question when it first appeared. In England, some have of late years cut a round hole about five inches diameter in a pane of the sash, and placed against it a circular plate of tin hung on an axis, and cut into vanes, which being separately bent a little obliquely, are acted upon by the entering air, so as to force the plate continually round like the vanes of a windmill. This admits the outward air, and by the continual whirling of the vanes, does in some degree disperse it. The noise only is a little inconvenient.

2. A second cause of the smoking of chimneys is, *their openings in the room being too large*; that is, too wide, too high, or both. Architects in general have no other ideas of proportion in the opening of a chimney, than what relate to symmetry and beauty, respecting the dimensions of the room†; while its

\* Plate I. Figure 2.

† See Appendix, No. I.

true proportion, respecting its function and utility, depends on quite other principles; and they might as properly proportion the step in a staircase to the height of the story, instead of the natural elevation of men's legs in mounting. The proportion then to be regarded, is what relates to the height of the funnel: for as the funnels in the different stories of a house are necessarily of different heights or lengths, that from the lowest floor being the highest or longest, and those of the other floors shorter and shorter, till we come to those in the garrets, which are of course the shortest; and the force of draught being, as already said, in proportion to the height of funnel filled with rarefied air; and a current of air from the room into the chimney, sufficient to fill the opening, being necessary to oppose and prevent the smoke coming out into the room; it follows that the openings of the longest funnels may be larger, and that those of the shorter funnels should be smaller: for if there be a large opening to a chimney that does not draw strongly, the funnel may happen to be furnished with the air it demands by a partial current entering on one side of the opening, and, leaving the other side free of any opposing current, may permit the smoke to issue there into the room. Much too of the force of draught in a funnel depends on the degree of rarefaction in the air it contains, and that depends on the nearness to the fire of its passage in entering the funnel. If  
it

it can enter far from the fire on each side, or far above the fire in a wide or high opening, it receives little heat in passing by the fire, and the contents of the funnel is by that means less different in levity from the surrounding atmosphere, and its force in drawing consequently weaker. Hence, if too large an opening be given to chimneys in upper rooms, those rooms will be smoky: on the other hand, if too small openings be given to chimneys in the lower rooms, the entering air operating too directly and violently on the fire, and afterwards strengthening the draught as it ascends the funnel, will consume the fuel too rapidly.

*Remedy.* As different circumstances frequently mix themselves in these matters, it is difficult to give precise dimensions for the openings of all chimneys. Our fathers made them generally much too large; we have lessened them; but they are often still of greater dimension than they should be, the human eye not being easily reconciled to sudden and great changes. If you suspect that your chimney smokes from the too great dimension of its opening, contract it by placing moveable boards so as to lower and narrow it gradually, till you find the smoke no longer issues into the room. The proportion so found will be that which is proper for that chimney, and you may employ the bricklayer or mason to reduce it accordingly. However, as, in building new houses, something must be sometimes hazarded,

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I would make the openings in my lower rooms about thirty inches square and eighteen deep ; and those in the upper, only eighteen inches square, and not quite so deep ; the intermediate ones diminishing in proportion as the height of funnel diminished. In the larger openings, billets of two feet long, or half the common length of cord-wood, may be burnt conveniently ; and for the smaller, such wood may be sawed into thirds. Where coals are the fuel, the grates will be proportioned to the openings. The same depth is nearly necessary to all, the funnels being all made of a size proper to admit a chimney-sweeper. If, in large and elegant rooms, custom or fancy should require the appearance of a larger chimney, it may be formed of expensive marginal decorations, in marble, &c. In time, perhaps that which is fittest in the nature of things may come to be thought handsomest. But at present, when men and women in different countries shew themselves dissatisfied with the forms God has given to their heads, waists, and feet, and pretend to shape them more perfectly, it is hardly to be expected that they will be content always with the best form of a chimney. And there are some, I know, so bi-gotted to the fancy of a large noble opening, that, rather than change it, they would submit to have damaged furniture, sore eyes, and skins almost smoked to bacon.

3. Another cause of smoky chimneys is, *too short a funnel*. This happens necessarily in some cases, as where a chimney is required in a low building; for, if the funnel be raised high above the roof, in order to strengthen its draught, it is then in danger of being blown down, and crushing the roof in its fall.

*Remedies.* Contract the opening of the chimney, so as to oblige all the entering air to pass through or very near the fire; whereby it will be more heated and rarefied, the funnel itself be more warmed, and its contents have more of what may be called the force of levity, so as to rise strongly, and maintain a good draught at the opening.

Or you may in some cases, to advantage, build additional stories over the low building, which will support a high funnel.

If the low building be used as a kitchen, and a contraction of the opening therefore inconvenient, a large one being necessary, at least when there are great dinners, for the free management of so many cooking utensils; in such case I would advise the building of two more funnels joining to the first, and having three moderate openings, one to each funnel, instead of one large one. When there is occasion to use but one, the other two may be kept shut by sliding plates, hereafter to be described\*; and two or all of them may be

\* See Appendix, No. II.



used together when wanted. This will indeed be an expence, but not an useless one, since your cooks will work with more comfort, see better than in a smoky kitchen what they are about, your victuals will be cleaner dressed, and not taste of smoke, as is often the case; and to render the effect more certain, a stack of three funnels may be safely built higher above the roof than a single funnel.

The case of too short a funnel is more general than would be imagined, and often found where one would not expect it. For it is not uncommon, in ill-contrived buildings, instead of having a funnel for each room or fire-place, to bend and turn the funnel of an upper room so as to make it enter the side of another funnel that comes from below. By this means the upper room funnel is made short of course, since its length can only be reckoned from the place where it enters the lower room funnel; and that funnel is also shortened by all the distance between the entrance of the second funnel and the top of the stack: for all that part being readily supplied with air through the second funnel, adds no strength to the draught, especially as that air is cold when there is no fire in the second chimney. The only easy remedy here is, to keep the opening shut of that funnel in which there is no fire.

4. Another very common cause of the smoking of chimneys is, *their overpowering one another*. For instance, if there be two chimneys  
in



in one large room, and you make fires in both of them, the doors and windows close shut, you will find that the greater and stronger fire shall overpower the weaker, and draw air down its funnel to supply its own demand; which air descending in the weaker funnel will drive down its smoke, and force it into the room. If, instead of being in one room, the two chimneys are in two different rooms, communicating by a door, the case is the same whenever that door is open. In a very tight house, I have known a kitchen chimney on the lowest floor, when it had a great fire in it, overpower any other chimney in the house, and draw air and smoke into its room, as often as the door was opened communicating with the stair-case.

*Remedy.* Take care that every room have the means of supplying itself from without with the air its chimney may require, so that no one of them may be obliged to borrow from another, nor under the necessity of lending. A variety of these means have been already described.

5. Another cause of smoking is, *when the tops of chimneys are commanded by higher buildings, or by a hill*, so that the wind blowing over such eminences, falls like water over a dam, sometimes almost perpendicularly on the tops of the chimneys that lie in its way, and beats down the smoke contained in them.

*Remedy.* That commonly applied to this case, is a turncap made of tin or plate iron, covering the chimney above and on three sides, open on one side, turning on a spindle, and which being guided or governed by a vane, always presents its back to the current. This, I believe, may be generally effectual, though not certain, as there may be cases in which it will not succeed. Raising your funnels, if practicable, so as their tops may be higher, or at least equal with the commanding eminence, is more to be depended on. But the turning cap, being easier and cheaper, should first be tried. If obliged to build in such a situation, I would choose to place my doors on the side next the hill, and the backs of my chimneys on the furthest side; for then the column of air falling over the eminence, and of course pressing on that below, and forcing it to enter the doors or *was-ist-dases* on that side, would tend to balance the pressure down the chimneys, and leave the funnels more free in the exercise of their functions.

6. There is another case of command, the reverse of that last mentioned. It is where the commanding eminence is farther from the wind than the chimney commanded. To explain this a figure may be necessary. Suppose then a building, whose side *A* happens to be exposed to the wind, and forms a kind of dam against its progress\*. The air obstructed by this

\* Plate I. Figure 3.

dam will, like water, press and search for passages through it; and finding the top of the chimney *B*, below the top of the dam, it will force itself down that funnel, in order to get through by some door or window open on the other side of the building. And if there be a fire in such chimney, its smoke is of course beat down, and fills the room.

*Remedy.* I know of but one, which is, to raise such funnel higher than the roof, supporting it, if necessary, by iron bars. For a turncap in this case has no effect, the dammed up air pressing down through it in whatever position the wind may have placed its opening.

I know a city in which many houses are rendered smoky by this operation; for their kitchens being built behind, and connected by a passage with the houses, and the tops of the kitchen chimneys lower than the tops of the houses, the whole side of a street, when the wind blows against its back, forms such a dam as above described; and the wind so obstructed forces down those kitchen chimneys (especially when they have but weak fires in them) to pass through the passage and house into the street. Kitchen chimneys so formed and situated have another inconvenience: in summer, if you open your upper room windows for air, a light breeze blowing over your kitchen chimney towards the house, though not strong enough to force down its smoke as aforesaid,

is sufficient to waft it into your windows, and fill the rooms with it; which, besides the disagreeableness, damages your furniture.

7. Chimneys, otherwise drawing well, are sometimes made to smoke by *the improper and inconvenient situation of a door*. When the door and chimney are on the same side of the room as in the figure \*, if the door *A*, being in the corner, is made to open against the wall, which is common, as being there, when open, more out of the way, it follows, that when the door is only opened in part, a current of air rushing in, passes along the wall into and across the opening of the chimney *B*, and flirts some of the smoke out into the room. This happens more certainly when the door is shutting; for then the force of the current is augmented, and becomes very inconvenient to those who, warming themselves by the fire, happen to sit in its way.

The *Remedies* are obvious and easy. Either put an intervening screen from the wall round great part of the fire-place; or, which is perhaps preferable, shift the hinges of your door, so as it may open the other way, and, when open, throw the air along the other wall.

8. A room that has no fire in its chimney is sometimes filled with *smoke, which is received at the top of its funnel, and descends into the room*. In a former paper † I have already ex-

\* Plate I. Figure 4.

† See Appendix, No. II.

plained the descending currents of air in cold funnels; it may not be amiss however to repeat here, that funnels without fires have an effect, according to their degree of coldness or warmth, on the air that happens to be contained in them. The surrounding atmosphere is frequently changing its temperature; but stacks of funnels, covered from winds and sun by the house that contains them, retain a more equal temperature. If, after a warm season, the outward air suddenly grows cold, the empty warm funnels begin to draw strongly upward; that is, they rarefy the air contained in them, which of course rises, cooler air enters below to supply its place, is rarefied in its turn, and rises; and this operation continues, till the funnel grows cooler, or the outward air warmer, or both, when the motion ceases. On the other hand, if, after a cold season, the outward air suddenly grows warm, and of course lighter, the air contained in the cool funnels, being heavier, descends into the room; and the warmer air which enters their tops, being cooled in its turn, and made heavier, continues to descend; and this operation goes on, till the funnels are warmed by the passing of warm air through them, or the air itself grows cooler. When the temperature of the air and of the funnels is nearly equal, the difference of warmth in the air between day and night is sufficient to produce these currents, the air will begin to ascend the funnels as the cool of the evening



comes on, and this current will continue till perhaps nine or ten o'clock the next morning, when it begins to hesitate; and as the heat of the day approaches, it sets downwards, and continues so till towards evening, when it again hesitates for some time, and then goes upwards constantly during the night, as before mentioned. Now when smoke issuing from the tops of neighbouring funnels passes over the tops of funnels which are at the time drawing downwards, as they often are in the middle part of the day, such smoke is of necessity drawn into these funnels, and descends with the air into the chamber.

The *Remedy* is, to have a sliding plate, hereafter described \*, that will shut perfectly the offending funnel.

9. Chimneys which generally draw well, do nevertheless sometimes give smoke into the rooms, *it being driven down by strong winds passing over the tops of their funnels*, though not descending from any commanding eminence. This case is most frequent where the funnel is short, and the opening turned from the wind. It is the more grievous when it happens to be a cold wind that produces the effect, because when you most want your fire you are sometimes obliged to extinguish it. To understand this, it may be considered that the rising light air, to obtain a free issue from

\* See Appendix, No. II.



the funnel, must push out of its way, or oblige the air that is over it to rise. In a time of calm, or of little wind, this is done visibly, for we see the smoke that is brought up by that air rise in a column above the chimney. But when a violent current of air, that is, a strong wind, passes over the top of a chimney, its particles have received so much force, which keeps them in a horizontal direction, and follow each other so rapidly, that the rising light air has not strength sufficient to oblige them to quit that direction, and move upwards to permit its issue. Add to this, that some of the current passing over that side of the funnel which it first meets with, viz. at  $A^*$ , having been compressed by the resistance of the funnel, may expand itself over the flue, and strike the interior opposite side at  $B$ , from whence it may be reflected downwards, and from side to side, in the direction of the pricked lines  $c c c$ .

*Remedies.* In some places, particularly in Venice, where they have not stacks of chimneys, but single flues, the custom is to open or widen the top of the flue, rounding in the true form of a funnel†; which some think may prevent the effect just mentioned, for that the wind blowing over one of the edges into the funnel may be slanted out again on the other side by its form. I have had no experience of this;

\* Plate I. Figure 5.

† Plate I. Figure 6.

but I have lived in a windy country, where the contrary is practised, the tops of the flues being *narrowed* inwards, so as to form a slit for the issue of the smoke, long as the breadth of the funnel, and only four inches wide. This seems to have been contrived on a supposition that the entry of the wind would thereby be obstructed; and perhaps it might have been imagined, that the whole force of the rising warm air being condensed, as it were, in the narrow opening, would thereby be strengthened, so as to overcome the resistance of the wind. This however did not always succeed; for when the wind was at north-east, and blew fresh, the smoke was forced down by fits into the room I commonly sat in, so as to oblige me to shift the fire into another. The position of the slit of this funnel was indeed north-east and south-west. Perhaps if it had lain across the wind, the effect might have been different. But on this I can give no certainty. It seems a matter proper to be referred to experiment. Possibly a turncap might have been serviceable, but it was not tried.

Chimneys have not been long in use in England. I formerly saw a book, printed in the time of queen Elizabeth which remarked the then modern improvements of living, and mentioned among others the convenience of chimneys. "Our forefathers," said the author, "had no chimneys. There was in each dwelling-house only a place for a fire, and the  
" smoke

“ smoke went out through a hole in the roof;  
“ but now there is scarce a gentleman’s house  
“ in England that has not at least one chim-  
“ ney in it.”—When there was but one chimney, its top might then be opened as a funnel, and perhaps, borrowing the form from the Venetians, it was then the flue of a chimney got that name. Such is now the growth of luxury, that in both England and France we must have a chimney for every room, and in some houses every possessor of a chamber, and almost every servant, will have a fire; so that the flues being necessarily built in stacks, the opening of each as a funnel is impracticable. This change of manners soon consumed the firewood of England, and will soon render fuel extremely scarce and dear in France, if the use of coals be not introduced in the latter kingdom, as it has been in the former, where it at first met with opposition; for there is extant in the records of one of queen Elizabeth’s parliaments, a motion made by a member, reciting, “ that many dyers, brewers, smiths,  
“ and other artificers of London, had of late  
“ taken to the use of pitcoal for their fires,  
“ instead of wood, which filled the air with  
“ noxious vapours and smoke, very prejudicial  
“ to the health, particularly of persons coming out of the country; and therefore moving that a law might pass to prohibit the  
“ use of such fuel (at least during the session  
“ of parliament) by those artificers.”—It seems  
it

it was not then commonly used in private houses. Its supposed unwholesomeness was an objection. Luckily the inhabitants of London have got over that objection, and now think it rather contributes to render their air salubrious, as they have had no general pestilential disorder since the general use of coals, when, before it, such were frequent. Paris still burns wood at an enormous expence continually augmenting, the inhabitants having still that prejudice to overcome. In Germany you are happy in the use of stoves, which save fuel wonderfully: your people are very ingenious in the management of fire; but they may still learn something in that art from the Chinese\*, whose country being greatly populous and fully cultivated, has little room left for the growth of wood, and having not much other fuel that is good, have been forced upon many inventions, during a course of ages, for making a little fire go as far as possible.

I have thus gone through all the common causes of the smoking of chimneys that I can at present recollect as having fallen under my observation; communicating the remedies that I have known successfully used for the different cases, together with the principles on which both the disease and the remedy depend, and confessing my ignorance wherever I have been sensible of it. You will do well, if you pub-

\* See Appendix, No. III.



lish, as you propose, this letter, to add in notes, or as you please, such observations as may have occurred to your attentive mind; and if other philosophers will do the same, this part of science, though humble, yet of great utility, may in time be perfected. For many years past, I have rarely met with a case of a smoky chimney, which has not been solvable on these principles, and cured by these remedies, where people have been willing to apply them: which is indeed not always the case; for many have prejudices in favour of the nostrums of pretending chimney-doctors and fumists, and some have conceits and fancies of their own, which they rather choose to try, than to lengthen a funnel, alter the size of an opening, or admit air into a room, however necessary; for some are as much afraid of fresh air as persons in the hydrophobia are of fresh water. I myself had formerly this prejudice, this *aerophobia*, as I now account it, and dreading the supposed dangerous effects of cool air, I considered it as an enemy, and closed with extreme care every crevice in the rooms I inhabited. Experience has convinced me of my error. I now look upon fresh air as a friend; I even sleep with an open window. I am persuaded that no common air from without, is so unwholesome as the air within a close room that has been often breathed and not changed. Moist air too, which formerly I thought pernicious, gives me now no apprehensions: for considering that no  
dampness



dampness of air applied to the outside of my skin, can be equal to what is applied to and touches it within, my whole body being full of moisture, and finding that I can lie two hours in a bath twice a week, covered with water, which certainly is much damper than any air can be, and this for years together, without catching cold, or being in any other manner disordered by it, I no longer dread mere moisture, either in air or in sheets or shirts: and I find it of importance to the happiness of life, the being freed from vain terrors, especially of objects that we are every day exposed inevitably to meet with. You physicians have of late happily discovered, after a contrary opinion had prevailed some ages, that fresh and cool air does good to persons in the small-pox and other fevers. It is to be hoped that in another century or two we may all find out, that it is not bad even for people in health. And as to moist air, here I am at this present writing in a ship with above forty persons, who have had no other but moist air to breathe for six weeks past; every thing we touch is damp, and nothing dries; yet we are all as healthy as we should be on the mountains of Switzerland, whose inhabitants are not more so than those of Bermuda or St. Helena, islands on whose rocks the waves are dashed into millions of particles, which fill the air with damp, but produce no diseases, the moisture being pure, unmixed with the poisonous vapours

vapours arising from putrid marshes and stagnant pools, in which many insects die, and corrupt the water. These places only, in my opinion (which however I submit to yours), afford unwholesome air; and that it is not the mere water contained in damp air, but the volatile particles of corrupted animal matter mixed with that water, which renders such air pernicious to those who breathe it. And I imagine it a cause of the same kind that renders the air in close rooms, where the perspirable matter is breathed over and over again by a number of assembled people, so hurtful to health. After being in such a situation, many find themselves affected by that *febricula*, which the English alone call *a cold*, and, perhaps from the name, imagine that they caught the malady by *going out* of the room, when it was in fact by being in it.

You begin to think that I wander from my subject, and go out of my depth. So I return again to my chimneys.

We have of late many lecturers in experimental philosophy. I have wished that some of them would study this branch of that science, and give experiments in it as a part of their lectures. The addition to their present apparatus need not be very expensive. A number of little representations of rooms, composed each of five panes of sash glass, framed in wood at the corners, with proportionable doors, and moveable glass chimneys, with openings of different

ferent fizes, and different lengths of funnel, and some of the rooms so contrived as to communicate on occasion with others, so as to form different combinations, and exemplify different cases; with quantities of green wax taper cut into pieces of an inch and half, sixteen of which stuck together in a square, and lit, would make a strong fire for a little glass chimney, and blown out would continue to burn and give smoke as long as desired: with such an apparatus all the operations of smoke and rarefied air in rooms and chimneys might be seen through their transparent sides; and the effect of winds on chimneys, commanded or otherwise, might be shewn by letting the entering air blow upon them through an opened window of the lecturer's chamber, where it would be constant while he kept a good fire in his chimney. By the help of such lectures our fumists would become better instructed. At present they have generally but one remedy, which perhaps they have known effectual in some one case of smoky chimneys, and they apply that indiscriminately to all the other cases, without success,—but not without expence to their employers.

With all the science, however, that a man shall suppose himself possessed of in this article, he may sometimes meet with cases that shall puzzle him. I once lodged in a house at London, which, in a little room, had a single chimney and funnel. The opening was very small,

small, yet it did not keep in the smoke, and all attempts to have a fire in this room were fruitless. I could not imagine the reason, till at length observing that the chamber over it, which had no fire-place in it, was always filled with smoke when a fire was kindled below, and that the smoke came through the cracks and crevices of the wainscot; I had the wainscot taken down, and discovered that the funnel which went up behind it, had a crack many feet in length, and wide enough to admit my arm, a breach very dangerous with regard to fire, and occasioned probably by an apparent irregular settling of one side of the house. The air entering this breach freely, destroyed the drawing force of the funnel. The remedy would have been, filling up the breach, or rather rebuilding the funnel: but the landlord rather chose to stop up the chimney.

Another puzzling case I met with at a friend's country house near London. His best room had a chimney in which, he told me, he never could have a fire, for all the smoke came out into the room. I flattered myself I could easily find the cause, and prescribe the cure. I had a fire made there, and found it as he said. I opened the door, and perceived it was not want of air. I made a temporary contraction of the opening of the chimney, and found that it was not its being too large that caused the smoke to issue. I went out and looked up at the top of the

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chimney:



chimney: its funnel was joined in the same stack with others, some of them shorter, that drew very well, and I saw nothing to prevent its doing the same. In fine, after every other examination I could think of, I was obliged to own the insufficiency of my skill. But my friend, who made no pretension to such kind of knowledge, afterwards discovered the cause himself. He got to the top of the funnel by a ladder, and, looking down, found it filled with twigs and straw, cemented by earth, and lined with feathers. It seems the house, after being built, had stood empty some years before he occupied it; and he concluded that some large birds had taken the advantage of its retired situation to make their nest there. The rubbish, considerable in quantity, being removed, and the funnel cleared, the chimney drew well, and gave satisfaction.

In general, smoke is a very tractable thing, easily governed and directed, when one knows the principles, and is well informed of the circumstances. You know I made it *descend* in my Pennsylvania stove. I formerly had a more simple construction, in which the same effect was produced, but visible to the eye. It was composed of two plates *AB* and *CD*, placed as in the figure\*. The lower plate *AB* rested with its edge in the angle made by the hearth with the back of the chimney. The upper plate was fixed to the breast, and lapt over the

\* Plate I. Figure 7.



lower about six inches, leaving a space of four inches wide, and the length of the plates (near two feet) between them. Every other passage of air into the funnel was well stopped. When therefore a fire was made at *E*, for the first time with charcoal, till the air in the funnel was a little heated through the plates, and then wood laid on, the smoke would rise to *A*, turn over the edge of that plate, descend to *D*, then turn under the edge of the upper plate, and go up the chimney. It was pretty to see, but of no great use. Placing therefore the under plate in a higher situation, I removed the upper plate *CD*, and placed it perpendicularly, so that the upper edge of the lower plate *AB* came within about three inches of it\*, and might be pushed farther from it, or suffered to come nearer to it, by a moveable wedge between them. The flame then ascending from the fire at *E*, was carried to strike the upper plate, made it very hot, and its heat rose and spread with the rarefied air into the room.

I believe you have seen in use with me, the contrivance of a sliding plate over the fire, seemingly placed to oppose the rising of the smoke, leaving but a small passage for it, between the edge of the plate and the back of the chimney. It is particularly described, and its uses explained, in my former printed letter, and I mention it here only as another instance of the tractability of smoke†.

\* Plate I. Figure 8.

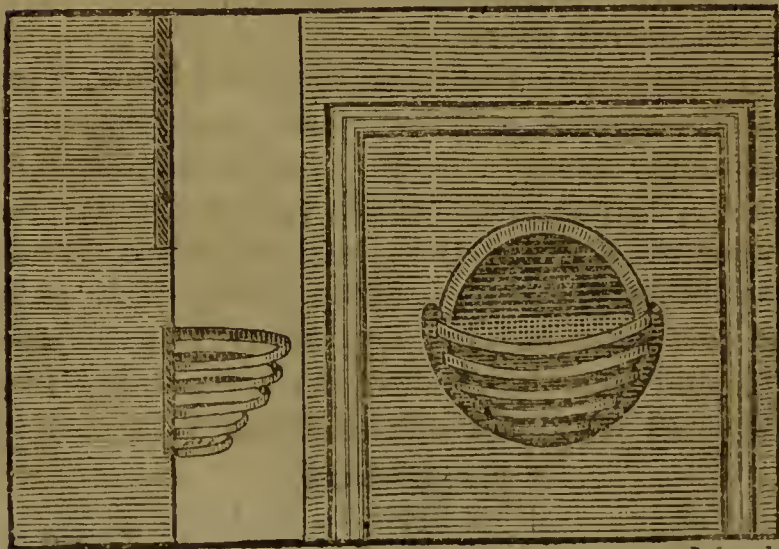
† See Appendix, No. II.

What is called the Staffordshire chimney, affords an example of the same kind. The opening of the chimney is bricked up, even with the fore edge of its jams, leaving open only a passage over the grate of the same width, and perhaps eight inches high. The grate consists of semicircular bars, their upper bar of the greatest diameter, the others under it smaller and smaller, so that it has the appearance of half a round basket. It is, with the coals it contains, wholly without the wall that shuts up the chimney, yet the smoke bends and enters the passage above it, the draught being strong, because no air can enter that is not obliged to pass near or through the fire, so that all that the funnel is filled with is much heated, and of course much rarefied.

### STAFFORDSHIRE FIRE-PLACE.

SIDE VIEW.

FRONT VIEW.



Much

Much more of the prosperity of a winter country depends on the plenty and cheapness of fuel, than is generally imagined. In travelling I have observed, that in those parts where the inhabitants can have neither wood, nor coal, nor turf, but at excessive prices, the working people live in miserable hovels, are ragged, and have nothing comfortable about them. But where fuel is cheap (or where they have the art of managing it to advantage) they are well furnished with necessaries, and have decent habitations. The obvious reason is, that the working hours of such people are the profitable hours, and they who cannot afford sufficient fuel, have fewer such hours in the twenty-four than those who have it cheap and plenty; for much of the domestic work of poor women, such as spinning, sewing, knitting; and of the men, in those manufactures that require little bodily exercise, cannot well be performed where the fingers are numbed with cold: those people, therefore, in cold weather, are induced to go to bed sooner, and lie longer in a morning, than they would do if they could have good fires or warm stoves to sit by; and their hours of work are not sufficient to produce the means of comfortable subsistence. Those public works, therefore, such as roads, canals, &c. by which fuel may be brought cheap into such countries from distant places, are of great utility; and those

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who

who promote them may be reckoned among the benefactors of mankind.

I have great pleasure in having thus complied with your request, and in the reflection that the friendship you honour me with, and in which I have ever been so happy, has continued so many years without the smallest interruption. Our distance from each other is now augmented, and nature must soon put an end to the possibility of my continuing our correspondence: but if consciousness and memory remain in a future state, my esteem and respect for you, my dear friend, will be everlasting.

B. F.

# A P P E N D I X.

## NOTES FOR THE LETTER UPON CHIMNEYS.

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### No. I.

THE latest work on architecture that I have seen, is that entitled NUTSHELLS, which appears to be written by a very ingenious man, and contains a table of the proportions of the openings of chimneys; but they relate solely to the proportions he gives his rooms, without the smallest regard to the funnels. And he remarks, respecting those proportions, that they are similar to the harmonic divisions of a monochord\*. He does not indeed lay much stress on this; but it shows that we like the appearance of principles; and where we have not true ones, we have some satisfaction in producing such as are imaginary.

### No. II.

THE description of the sliding plates here promised, and which hath been since brought into use under various names, with

\* "It may be just remarked here, that upon comparing these proportions with those arising from the common divisions of the monochord, it happens that the first answers to unison; and although the second is a discord, the third answers to the third minor, the fourth to the third major, the fifth to the fourth, the sixth to the fifth, and the seventh to the octave." NUTSHELLS, page 85.



some immaterial changes, is contained in a former letter to J. B. Esq. as follows:

*To J. B. Esq. at Boston, in New England.*

Dear Sir,                      London, Dec. 2, 1758.

I HAVE executed here an easy simple contrivance, that I have long since had in speculation, for keeping rooms warmer in cold weather than they generally are, and with less fire. It is this. The opening of the chimney is contracted, by brick-work faced with marble slabs, to about two feet between the jams, and the breast brought down to within about three feet of the hearth.—An iron frame is placed just under the breast, and extending quite to the back of the chimney, so that a plate of the same metal may slide horizontally backwards and forwards in the grooves on each side of the frame. This plate is just so large as to fill the whole space, and shut the chimney entirely when thrust quite in, which is convenient when there is no fire. Drawing it out, so as to leave a space between its further edge and the back, of about two inches; this space is sufficient for the smoke to pass; and so large a part of the funnel being stopt by the rest of the plate, the passage of warm air out of the room, up the chimney, is obstructed and retarded, and by that means much cold air is prevented from coming in through crevices, to supply its place. This effect is made manifest three ways.

ways. First, when the fire burns briskly in cold weather, the howling or whistling noise made by the wind, as it enters the room through the crevices, when the chimney is open as usual, ceases as soon as the plate is slid in to its proper distance. Secondly, opening the door of the room about half an inch, and holding your hand against the opening, near the top of the door, you feel the cold air coming in against your hand, but weakly, if the plate be in. Let another person suddenly draw it out, so as to let the air of the room go up the chimney; with its usual freedom where chimneys are open, and you immediately feel the cold air rushing in strongly. Thirdly, if something be set against the door, just sufficient, when the plate is in, to keep the door nearly shut, by resisting the pressure of the air that would force it open; then, when the plate is drawn out, the door will be forced open by the increased pressure of the outward cold air endeavouring to get in to supply the place of the warm air, that now passes out of the room to go up the chimney. In our common open chimneys, half the fuel is wasted, and its effect lost; the air it has warmed being immediately drawn off. Several of my acquaintance having seen this simple machine in my room, have imitated it at their own houses; and it seems likely to become pretty common. I describe it thus particularly to you, because I think it would be useful in *Boston*, where firing is often dear.

Mentioning chimneys puts me in mind of a property I formerly had occasion to observe in them, which I have not found taken notice of by others ; it is, that in the summer time, when no fire is made in the chimneys, there is, nevertheless, a regular draught of air through them ; continually passing upwards, from about five or six o'clock in the afternoon, till eight or nine o'clock the next morning, when the current begins to slacken and hesitate a little, for about half an hour, and then sets as strongly down again, which it continues to do till towards five in the afternoon, then slackens and hesitates as before, going sometimes a little up, then a little down, till in about half an hour it gets a steady upward current for the night, which continues till eight or nine the next day ; the hours varying a little as the days lengthen and shorten, and sometimes varying from sudden changes in the weather ; as if, after being long warm, it should begin to grow cool about noon, while the air was coming down the chimney, the current will then change earlier than the usual hour, &c.

This property in chimneys I imagine we might turn to some account, and render improper, for the future, the old saying, *as useless as a chimney in summer*. If the opening of the chimney, from the breast down to the hearth, be closed by a slight moveable frame or two, in the manner of doors, covered with canvas, that will let the air through, but keep out the

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the flies; and another little frame set within upon the hearth, with hooks on which to hang joints of meat, fowls, &c. wrapt well in wet linen cloths, three or four fold; I am confident that if the linen is kept wet, by sprinkling it once a day, the meat would be so cooled by the evaporation, carried on continually by means of the passing air, that it would keep a week or more in the hottest weather. Butter and milk might likewise be kept cool, in vessels or bottles covered with wet cloths. A shallow tray, or keeler, should be under the frame to receive any water that might drip from the wetted cloths. I think, too, that this property of chimneys might, by means of smoke-jack vanes, be applied to some mechanical purposes, where a small but pretty constant power only is wanted.

If you would have my opinion of the cause of this changing current of air in chimneys, it is, in short, as follows. In summer time there is generally a great difference in the warmth of the air at mid-day and mid-night, and, of course, a difference of specific gravity in the air, as the more it is warmed the more it is rarefied. The funnel of a chimney being for the most part surrounded by the house, is protected, in a great measure, from the direct action of the sun's rays, and also from the coldness of the night air. It thence preserves a middle temperature between the heat of the day, and the coldness of the night. This

middle temperature it communicates to the air contained in it. If the state of the outward air be cooler than that in the funnel of the chimney, it will, by being heavier, force it to rise, and go out at the top. What supplies its place from below, being warmed, in its turn, by the warmer funnel, is likewise forced up by the colder and weightier air below, and so the current is continued till the next day, when the sun gradually changes the state of the outward air, makes it first warm as the funnel of the chimney can make it (when the current begins to hesitate), and afterwards warmer. Then the funnel being cooler than the air that comes into it, cools that air, makes it heavier than the outward air, of course it descends; and what succeeds it from above being cooled in its turn, the descending current continues till towards evening, when it again hesitates and changes its course, from the change of warmth in the outward air, and the nearly remaining same middle temperature in the funnel.

Upon this principle, if a house were built behind *Beacon-hill*, an adit carried from one of the doors into the hill horizontally, till it met with a perpendicular shaft sunk from its top, it seems probable to me, that those who lived in the house, would constantly, in the heat even of the calmest day, have as much cool air passing through the house, as they should choose; and the same, though reversed in its current, during the stillest night.

I think,



I think, too, this property might be made of use to miners ; as where several shafts or pits are sunk perpendicularly into the earth, communicating at bottom by horizontal passages, which is a common case, if a chimney of thirty or forty feet high were built over one of the shafts, or so near the shaft, that the chimney might communicate with the top of the shaft, all air being excluded but what should pass up or down by the shaft, a constant change of air would, by this means, be produced in the passages below, tending to secure the workmen from those damps which so frequently incommoded them : for the fresh air would be almost always going down the open shaft to go up the chimney, or down the chimney to go up the shaft. Let me add one observation more, which is, that if that part of the funnel of a chimney, which appears above the roof of a house, be pretty long, and have three of its sides exposed to the heat of the sun successively, viz. when he is in the east, in the south, and in the west, while the north side is sheltered by the building from the cold northerly winds ; such a chimney will often be so heated by the sun, as to continue the draught strongly upwards, through the whole twenty-four hours, and often for many days together. If the outside of such a chimney be painted black, the effect will be still greater, and the current stronger.

## No. III.

IT is said the northern Chinese have a method of warming their ground-floors, which is ingenious. These floors are made of tile a foot square and two inches thick, their corners being supported by bricks set on end, that are a foot long and four inches square; the tiles, too, join into each other, by ridges and hollows along their sides. This forms a hollow under the whole floor, which on one side of the house has an opening into the air, where a fire is made, and it has a funnel rising from the other side to carry off the smoke. The fuel is a sulphureous pitcoal, the smell of which in the room is thus avoided, while the floor, and of course the room, is well warmed. But as the under side of the floor must grow foul with soot, and a thick coat of soot prevents much of the direct application of the hot air to the tiles, I conceive that burning the smoke, by obliging it to descend through red coals, would in this construction be very advantageous, as more heat would be given by the flame than by the smoke, and the floor being thereby kept free from soot, would be more heated with less fire. For this purpose I would propose erecting the funnel close to the grate, so as to have only an iron plate between the fire and the funnel, through which plate the air in the funnel being heated, it will be sure to draw well, and force the smoke  
to

to descend, as in the figure\*, where *A* is the funnel or chimney, *B* the grate on which the fire is placed, *C* one of the apertures through which the descending smoke is drawn into the channel *D* of figure 10, along which channel it is conveyed by a circuitous route, as designated by the arrows, until it arrives at the small aperture *E*, figure 10, through which it enters the funnel *F*. *G* in both figures is the iron plate against which the fire is made, which being heated thereby, will rarefy the air in that part of the funnel, and cause the smoke to ascend rapidly. The flame thus dividing from the grate to the right and left, and turning in passages disposed, as in figure 10, so as that every part of the floor may be visited by it before it enters the funnel *F*, by the two passages *EE*, very little of the heat will be lost, and a winter room thus rendered very comfortable.

## No. IV.

**PAGE 12.** *Few can imagine, &c.* It is said the Icelanders have very little fuel, chiefly drift wood that comes upon their coast. To receive more advantage from its heat, they make their doors low, and have a stage round the room above the door, like a gallery, wherein the women can sit and work, the men read or write, &c. The roof being tight, the warm air is confined by it, and kept from rising higher

\* Plate I. Figure 9.

and

and escaping ; and the cold air, which enters the house when the door is opened, cannot rise above the level of the top of the door, because it is heavier than the warm air above the door, and so those in the gallery are not incommoded by it. Some of our too lofty rooms might have a stage so constructed as to make a temporary gallery above, for the winter, to be taken away in summer. Sedentary people would find much comfort there in cold weather.

## No. V.

PAGE 37. *Where they have the art of managing it, &c.* In some houses of the lower people among the northern nations of Europe, and among the poorer sort of Germans in Pennsylvania, I have observed this construction, which appears very advantageous. *A* is the kitchen with its chimney; *B* an iron stove in the stove-room\*. In a corner of the chimney is a hole through the back into the stove, to put in fuel, and another hole above it to let the smoke of the stove come back into the chimney. As soon as the cooking is over, the brands in the kitchen chimney are put through the hole to supply the stove, so that there is seldom more than one fire burning at a time. In the floor over the stove-room is a small trap-door, to let the warm air rise occasionally into the chamber. Thus the whole house

\* Plate I. Figure II.

is warmed at little expence of wood, and the stove-room kept constantly warm ; so that in the coldest winter nights, they can work late, and find the room still comfortable when they rise to work early. An English farmer in America, who makes great fires in large open chimneys, needs the constant employment of one man to cut and haul wood for supplying them ; and the draught of cold air to them is so strong, that the heels of his family are frozen while they are scorching their faces, and the room is never warm, so that little sedentary work can be done by them in winter. The difference in this article alone of œconomy shall, in a course of years, enable the German to buy out the Englishman, and take possession of his plantation.

#### MISCELLANEOUS OBSERVATIONS.

**C**HIMNEYS whose funnels go up in the north wall of a house, and are exposed to the north winds, are not so apt to draw well as those in a south wall ; because, when rendered cold by those winds, they draw downwards.

Chimneys enclosed in the body of a house are better than those whose funnels are exposed in cold walls.

Chimneys in stacks are apt to draw better than separate funnels, because the funnels that have constant fires in them, warm the others in some degree that have none.

One of the funnels in a house I once occu-  
E
pied,



pied, had a particular funnel joined to the south side of the stack, so that three of its sides were exposed to the sun in the course of the day, viz. the east side  $E^*$  during the morning, the south side  $S$  in the middle part of the day, and the west side  $W$  during the afternoon, while its north side was sheltered by the stack from the cold winds. This funnel, which came from the ground floor, and had a considerable height above the roof, was constantly in a strong drawing state, day and night, winter and summer.

Blackening of funnels exposed to the sun, would probably make them draw still stronger.

In Paris I saw a fire-place so ingeniously contrived as to serve conveniently two rooms, a bedchamber, and a study. The funnel over the fire was round. The fire-place was of cast iron, having an upright back  $A^\dagger$ , and two horizontal semicircular plates  $BC$ , the whole so ordered as to turn on the pivots  $DE$ . The plate  $B$  always stopped that part of the round funnel that was next to the room without fire, while the other half of the funnel over the fire was always open. By this means a servant in the morning could make a fire on the hearth  $C$ , then in the study, without disturbing the master by going into his chamber; and the master when he rose, could with a touch of his foot turn the chimney on its pivots, and bring the fire into his chamber, keep it there as long

\* Plate I. Figure 12.

† Plate I. Figure 13.

as he wanted it, and turn it again when he went out into his study. The room which had no fire in it was also warmed by the heat coming through the back plate, and spreading in the room, as it could not go up the chimney.

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*To His Excellency BENJAMIN FRANKLIN, Esq.  
L. L. D. President of the State of Pennsylvania, and of the American Philosophical Society, &c.*

S I R,

Philadelphia, January 12, 1786.

**T**HE subject of smoky chimneys, of which I had the honour of conversing with you at your own house last evening, is of so much importance to every individual, as well as to every private family, that too much light cannot be thrown upon it.

*A smoky house, and a scolding wife,  
Are (said to be) two of the greatest ills in life.*

And however difficult it may be to remedy one of those ills, yet any advances we may be able to make towards removing the inconveniences arising from the other, cannot fail to be favourably received by the public. As they are shortly to be favoured with your sentiments on that subject, possibly the following observations, which were in fact occasioned by necessity, and are the result of my own experience, may not be altogether undeserving of notice.

When I left London, and went to live in Devonshire, in the latter end of the year 1777, it happened to be my lot to dwell in an old mansion which had been recently modernised, and had undergone a thorough repair. But as in most of the old houses in England, the chimneys, which were perhaps originally built for the purpose of burning wood, though they had been contracted in front, since coal fires came into general use, to the modern size, yet they were still, above, out of sight, extravagantly large. This method of building chimneys may perhaps have answered well enough while it was the custom to sit with the doors and windows open; but when the customs and manners of the people began to be more polished and refined, when building and architecture were improved, and they began to conceive the idea of making their chambers close, warm, and comfortable, these chimneys were found to smoke abominably, for want of a sufficient supply of air. This was exactly the case with the house in which I first lived, near Exeter, and I was under the necessity of trying every expedient I could think of to make it habitable.

The first thing I tried was that method of contracting the chimneys by means of earthen pots, much in use in England, which are made on purpose, and which are put upon the tops of them; but this method by no means answered. I then thought of contracting them below; but as the method of contracting them

in front to the size of a small coal-fire grate has an unsightly appearance, as it makes a disagreeable blowing like a furnace, and as it is the occasion of consuming a great deal of unnecessary fuel, the heat of which is immediately hurried up the chimney, I rejected this method, and determined to contract them above, a little out of sight. For this purpose I threw an arch across, and also drew them in at the sides. This had some effect; but as this contraction was made rather suddenly, and the smoke, by striking against the corners that were thereby occasioned, was apt to recoil, by which means some part of it was thrown out into the room, I determined to make the contraction more gradually, and therefore run it up at the back, where the depth of the chimney would admit of it, and also shelving or sloping in a conical kind of direction at the sides, as high as a man, standing upright, could conveniently reach, and by this means brought the cavity within the space of about twelve by fourteen or sixteen inches, which I found sufficiently large to admit a boy to go up and down to sweep the chimneys. This method I found to succeed perfectly well as to curing the chimneys of smoking, and it had this good effect, of making the rooms considerably warmer; and as this experiment succeeded so well, since the only use of a chimney is to convey away the smoke, I determined to carry it still farther, in order to ascertain, with precision, how much

space is absolutely necessary for that purpose, because all the rest that is shut up must be so much gained in warmth. Accordingly I laid a piece of slate across the remaining aperture, removable at pleasure, so as to contract the space above two thirds, leaving about three inches by twelve remaining open; but this space, except when the fire burnt remarkably clear, was scarcely sufficient to carry away the smoke. I therefore enlarged it to half the space, that is, to about six by seven or eight inches, which I found fully sufficient to carry away the smoke from the largest fires.

When I removed into the Bedford Circus in Exeter, though the house was modern, and almost perfectly new, yet the chimneys were large; in consequence of which almost every room of it smoked. My predecessor, who was the first inhabitant, had been at great expence in patent stoves, &c. but without effect; but by adopting the method I have just now described, I not only cured every chimney of smoking, but my house was remarked for being one of the warmest and most comfortable to live in of any in that large and opulent city.

The house I now live in, in Philadelphia, I am told, has always had the character of being both cold and smoky; and I was convinced, as soon as I saw the rooms and examined the chimneys, that it deserved that character; for though the rooms were close, the chimneys were large: and we shall ever find, that if

our



our chimneys are large, our rooms will be cold, even though they should be tolerably close and tight; because the constant rushing in of the cold air at the cracks and crevices, and also at every opening of the door, will be sufficient to chill the air as fast as it is heated, or to force the heated air up the chimney; but by contracting the chimneys I have cured it of both these defects. There was one remarkable circumstance attending the contraction of the chimney in the front parlour, which deserves to be attended to; which was, that before I applied the cast iron plate, which I made use of instead of slate, to diminish the space requisite for a chimney-sweeper's boy to go up and down, the suction or draught of air was so great, that it was with difficulty I could shut the door of the room, insomuch that I at first thought it was owing to a tightness of the hinges, which I imagined must be remedied; but upon applying the iron plate, by which the space was diminished one half, the door shut to with the greatest ease. This extraordinary pressure of the air upon the door of the room, or suction of the chimney, I take to be owing in some measure to the unusual height of the house.

Upon the whole, therefore, this fact seems clearly ascertained, viz. That the flue or size of the chimney ought always to be proportioned to the tightness and closeness of the room: some air is undoubtedly necessary to be admitted into the room in order to carry up the

E. 4

smoke,

smoke, otherwise, as you justly observed, we might as well expect smoke to arise out of an exhausted receiver; but if the flue is very large, either the room is tight, and the smoke will not ascend, or it is pretty open, and the consequence will be, that the air of your room will be so frequently and so constantly changed, that, as fast as it is heated, it will be hurried away, with the smoke, up the chimney, and of course your room will be constantly cold.

One great advantage attending this method of curing smoky chimneys is, that, in the first place, it makes no awkward or unsightly appearance, nothing being to be seen but what is usual to chimneys in common; and, in the second place, that it is attended with very little expence, a few bricks and mortar, with a plate or covering to the aperture, and a little labour, being all that is requisite. But in this new country, where crops of houses may be expected to rise almost as quick as fields of corn, when the principles upon which chimneys should be erected ought to be thoroughly understood, it is to be hoped, that not only this expence, small as it is, but that all the other inconveniences we have been speaking of, will be avoided, by constructing the flues of the chimneys sufficiently small.

From your humble servant,

THOMAS RUSTON.

*Description*

*Description of a new STOVE for burning of  
Pitcoal, and consuming all its Smoke.*

BY DR. B. FRANKLIN.

**T**OWARDS the end of the last century, an ingenious French philosopher, whose name I am sorry I cannot recollect, exhibited an experiment to show that very offensive things might be burnt in the middle of a chamber, such as woollen rags, feathers, &c. without creating the least smoke or smell. The machine in which the experiment was made, if I remember right, was of this form\*, made of plate iron. Some clear-burning charcoals were put into the opening of the short tube *A*, and supported there by the grate *B*. The air, as soon as the tubes grew warm, would ascend in the longer leg *C*, and go out at *D*, consequently air must enter at *A* descending to *B*. In this course it must be heated by the burning coals through which it passed, and rise more forcibly in the longer tube, in proportion to its degree of heat or rarefaction, and length of that tube. For such a machine is a kind of inverted syphon: and as the greater weight of water in the longer leg of a common syphon, in descending, is accompanied by an ascent of the same fluid in the shorter; so, in this inverted syphon, the greater quantity of levity of air in

\* Plate II. Figure 1.

the

the longer leg, in rising, is accompanied by the descent of air in the shorter. The things to be burned being laid on the hot coals at *A*, the smoke must descend through those coals, and be converted into flame, which, after destroying the offensive smell, comes out at the end of the longer tube as mere heated air.

Whoever would repeat this experiment with success, must take care that the part *AB*, of the short tube, be quite full of burning coals, so that no part of the smoke may descend and pass by them without going through them, and being converted into flame; and that the longer tube be so heated as that the current of ascending hot air is established in it before the things to be burnt are laid on the coals; otherwise there will be a disappointment.

It does not appear, either in the *Memoirs of the Academy of Sciences*, or *Philosophical Transactions of the English Royal Society*, that any improvement was ever made of this ingenious experiment, by applying it to useful purposes. But there is a German book, entitled *Vulcanus Famulus*, by John George Leutmann, P. D. printed at Wirtemberg in 1723, which describes, among a great variety of other stoves for warming rooms, one which seems to have been formed on the same principle, and probably from the hint thereby given, though the French experiment is not mentioned. This book being scarce, I have translated the chapter describing the stove, viz.

“ Vulcanus Famulans, by John George Leutmann, P. D. Wirtemberg, 1723.

“ C H A P. VII.

“ On a stove which draws downwards.

“ Here follows the description of a sort of  
 “ stove, which can easily be removed, and again  
 “ replaced, at pleasure. This drives the fire  
 “ down under itself, and gives no smoke, but  
 “ however a very unwholesome vapour.

“ In the figure, *A* is an iron vessel like a  
 “ funnel\*, in diameter at the top about twelve  
 “ inches; at the bottom, near the grate, about  
 “ five inches; its height twelve inches. This  
 “ is set on the barrel *C*, which is ten inches  
 “ diameter, and two feet long, closed at each  
 “ end *E E*. From one end rises a pipe or flue  
 “ about four inches diameter, on which other  
 “ pieces of pipe are set, which are gradually  
 “ contracted to *D*, where the opening is but  
 “ about two inches. Those pipes must toge-  
 “ ther be at least four feet high. *B* is an iron  
 “ grate. *F F* are iron handles guarded with  
 “ wood, by which the stove is to be lifted and  
 “ moved. It stands on three legs. Care must  
 “ be taken to stop well all the joints, that no  
 “ smoke may leak through.

“ When this stove is to be used, it must first  
 “ be carried into the kitchen, and placed in

\* Plate II. Figure 20. -

“ the



“ the chimney near the fire. There burning  
“ wood must be laid and left upon its grate  
“ till the barrel *C* is warm, and the smoke no  
“ longer rises at *A*, but descends towards *C*.  
“ Then it is to be carried into the room which  
“ it is to warm. When once the barrel *C*  
“ is warm, fresh wood may be thrown into the  
“ vessel *A* as often as one pleases; the flame  
“ descends, and without smoke, which is so  
“ consumed that only a vapour passes out at *D*.

“ As this vapour is unwholesome, and af-  
“ fects the head, one may be freed from it, by  
“ fixing in the wall of the room an inverted  
“ funnel, such as people use to hang over  
“ lamps, through which their smoke goes out  
“ as through a chimney. This funnel carries  
“ out all the vapour cleverly, so that one finds  
“ no inconvenience from it, even though the  
“ opening *D* be placed a span below the mouth  
“ of the said funnel *G*. The neck of the fun-  
“ nel is better when made gradually bending,  
“ than if turned in a right angle.

“ The cause of the draught downwards in  
“ the stove is the pressure of the outward air,  
“ which falling into the vessel *A* in a column  
“ of twelve inches diameter, finds only a re-  
“ sisting passage at the grate *B* of five inches,  
“ and one at *D* of two inches, which are much  
“ too weak to drive it back again; besides, *A*  
“ stands much higher than *B*, and so the pres-  
“ sure on it is greater and more forcible, and  
“ beats down the flame to that part where it  
“ finds

“ finds the least resistance. Carrying the machine first to the kitchen fire for preparation is on this account, that, in the beginning, the fire and smoke naturally ascend till the air in the close barrel *C* is made thinner by the warmth. When that vessel is heated, the air in it is rarefied, and then all the smoke and fire descends under it.

“ The wood should be thoroughly dry, and cut into pieces five or six inches long, to fit it for being thrown into the funnel, *A*.”  
Thus far the German book.

It appears to me, by Mr. Leutmann's explanation of the operation of this machine, that he did not understand the principles of it, whence I conclude he was not the inventor of it: and by the description of it, wherein the opening at *A* is made so large, and the pipe *ED* so short, I am persuaded he never made nor saw the experiment; for the first ought to be much smaller, and the last much higher, or it hardly will succeed. The carrying it in the kitchen too, every time the fire should happen to be out, must be so troublesome that it is not likely ever to have been in practice, and probably has never been shown but as a philosophical experiment. The funnel for conveying the vapour out of the room would besides have been uncertain in its operation, as a wind blowing against its mouth would drive the vapour back.

The stove I am about to describe, was also formed on the idea given by the French experiment,

riment, and completely carried into execution before I had any knowledge of the German invention; which I wonder should remain so many years in a country where men are so ingenious in the management of fire, without receiving long since the improvements I have given it.

### DESCRIPTION of the PARTS.

*A*, the bottom plate, which lies flat upon the hearth, with its partitions 1, 2, 3, 4, 5, 6, that are cast with it, and a groove *Z Z*, in which are to slide the bottom edges of the small plates *Y Y*, figure 12; which plates, meeting at *X*, close the front\*.

*B 1*, figure 3, is the cover plate showing its under side, with the grooves 1, 2, 3, 4, 5, 6, to receive the top edges of the partitions that are fixed to the bottom plate. It shows also the grate *W W*, the bars of which are cast in the plate, and a groove *V V*, which comes right over the groove *Z Z*, figure 2, receiving the upper edges of the small sliding plates *Y Y*, figure 12.

*B 2*, figure 4, shows the upper side of the same plate, with a square impression or groove for receiving the bottom mouldings *T T T T* of the three-sided box *C*, figure 5, which is cast in one piece.

*D*, figure 6, its cover, showing its under side with grooves to receive the upper edges *S S S* of the sides of *C*, figure 5; also a groove

\* Plate II. Figure 2.

*RR*, which, when the cover is put on, comes right over another *QQ* in *C*, figure 5, between which it is to slide.

*E*, figure 7, the front plate of the box.

*P*, a hole three inches diameter through the cover *D*, figure 6; over which hole stands the vase *F*, figure 8, which has a corresponding hole two inches diameter through its bottom.

The top of the vase opens at *OOO*, figure 8, and turns back upon a hinge behind when coals are to be put in; the vase has a grate within at *NN* of cast iron *H*, figure 9, and a hole in the top one inch and an half diameter to admit air, and to receive the ornamental brass gilt flame *M*, figure 10, which stands in that hole, and, being itself hollow and open, suffers air to pass through it to the fire.

*G*, figure 11, is a drawer of plate iron that slips in between in the partitions 2 and 3, figure 2, to receive the falling ashes. It is concealed when the small sliding plates *YY*, figure 12, are shut together.

*IIII*, figure 8, is a niche built of brick in the chimney, and plastered. It closes the chimney over the vase, but leaves two funnels, one in each corner, communicating with the bottom box *KK*, figure 2.

#### DIMENSIONS of the PARTS.

			Fect.	In.
Front of the bottom box	-	-	2	0
Height of its partitions	-	-	0	4 $\frac{1}{4}$
			Length	

	Feet.	In.
Length of No. 1, 2, 3, and 4, each -	1	3
Length of No. 5 and 6, each -	0	8 $\frac{1}{4}$
Breadth of the passage between No. 2 and 3 - - - - -	0	6
Breadth of the other passages, each	0	3 $\frac{1}{2}$
Breadth of the grate - - - -	0	6 $\frac{1}{2}$
Length of ditto - - - -	0	8
Bottom moulding of box <i>C</i> , square	1	0
Height of the sides of ditto -	0	4
Length of the back side - -	0	10
Length of the right and left sides, each - - - - -	0	9 $\frac{1}{2}$
Length of the front plate <i>E</i> , where longest - - - - -	0	11
The cover <i>D</i> , square - - - -	0	12
Hole in ditto, diameter - - -	0	3
Sliding plates <i>X X</i> , their length each - - - - -	1	0
----- their breadth each - - - - -	0	4 $\frac{1}{2}$
Drawer <i>G</i> , its length - - - -	1	0
----- breadth - - - -	0	5 $\frac{1}{4}$
----- depth - - - -	0	4
----- depth of its further end, only - - - - -	0	1
Grate <i>H</i> in the vase, its diameter to the extremity of its knobs -	0	5 $\frac{3}{4}$
Thickness of the bars at top -	0	0 $\frac{1}{4}$
----- at bottom, less - - - - -	0	0
Depth of the bars at the top -	0	0 $\frac{3}{4}$
	Height	



					Fect.	In.
Height of the vase	-	-	-	-	1	6
Diameter of the opening <i>OO</i> , in						
the clear	-	-	-	-	0	8
———— of the air-hole at top	-				0	1½
———— of the flame-hole at bot-						
tom	-	-	-	-	0	2

*To fix this Machine.*

Spread mortar on the hearth to bed the bottom plate *A*; then lay that plate level, equally distant from each jamb, and projecting out as far as you think proper. Then putting some Windsor loam in the grooves of the cover *B*, lay that on; trying the sliding plates *YY*, to see if they move freely in the grooves *ZZ*, *VV*, designed for them.

Then begin to build the niche, observing to leave the square corners of the chimney unfilled; for they are to be funnels. And observe also to leave a free open communication between the passages at *KK*, and the bottom of those funnels; and mind to close the chimney above the top of the niche, that no air may pass up that way. The concave back of the niche will rest on the circular iron partition 1 *A* 4, figure 2; then, with a little loam put on the box *C* over the grate, the open side of the box in front.

Then, with loam in three of its grooves, the groove *RR* being left clean, and brought directly over the groove *QQ*, in the box, put

on the cover *D*, trying the front plate *E*, to see if it slides freely in those grooves.

Lastly, set on the vase, which has small holes in the moulding of its bottom to receive two iron pins that rise out of the plate *D* at *I I*, for the better keeping it steady.

Then putting in the grate *H*, which rests on its three knobs *H H H* against the inside of the vase; and slipping the drawer into its place, the machine is fit for use.

*To use it.*

Let the first fire be made after eight in the evening, or before eight in the morning; for at those times and between those hours all night, there is usually a draft up a chimney, though it has long been without fire; but between those hours in the day there is often in a cold chimney a draft downwards, when, if you attempt to kindle a fire, the smoke will come into the room.

But to be certain of your proper time, hold a flame over the air-hole at the top. If the flame is drawn strongly down for a continuance, without whiffing, you may begin to kindle a fire.

First put in a few charcoals on the grate *H*,  
Lay some small sticks on the charcoals,  
Lay some pieces of paper on the sticks,  
Kindle the paper with a candle,

Then shut down the top, and the air will  
pass down through the air-hole: blow the  
flame

flame of the paper down through the sticks, kindle them, and their flame passing lower, kindles the charcoal.

When the charcoal is well kindled, lay on it the sea-coals, observing not to choak the fire by putting on too much at first.

The flame descending through the hole in the bottom of the vase, and that in plate *D* into the box *C*, passes down farther through the grate *W W* in plate *B* 1, then passes horizontally towards the back of the chimney; there dividing, and turning to the right and left, one part of it passes round the far end of the partition 2; then coming forward, it turns round the near end of partition 1; then moving backward, it arrives at the opening into the bottom of one of the upright corner funnels behind the niche, through which it ascends into the chimney, thus heating that half of the box and that side of the niche. The other part of the divided flame passes round the far end of partition 3, round the near end of partition 4, and so into and up the other corner funnel, thus heating the other half of the box, and the other side of the niche. The vase itself, and the box *C*, will also be very hot; and the air surrounding them being heated, and rising, as it cannot get into the chimney, it spreads in the room; colder air succeeding is warmed in its turn, rises and spreads, till by the continual circulation the whole is warmed.

If you should have occasion to make your  
F 2 first

first fire at hours not so convenient as those above mentioned, and when the chimney does not draw, do not begin it in the vase, but in one or more of the passages of the lower plate, first covering the mouth of the vase. After the chimney has drawn a while with the fire thus low, and begins to be a little warm, you may close those passages, and kindle another fire in the box C, leaving its sliding shutter a little open; and when you find after some time that the chimney being warmed draws forcibly, you may shut that passage, open your vase, and kindle your fire there, as above directed. The chimney well warmed by the first day's fire will continue to draw constantly all winter, if fires are made daily.

You will, in the management of your fire, have need of the following implements :

A pair of small light tongs, twelve or fifteen inches long, plate II. figure 13.

A light poker about the same length, with a flat broad point, figure 14.

A rake to draw ashes out of the passages of the lower plate, where the lighter kind escaping the ash-box, will gather by degrees, and, perhaps once in a week or ten days, require being removed, figure 15.

And a fork, with its prongs wide enough to slip on the neck of the vase cover, in order to raise and open it when hot, to put in fresh coals, figure 16.

In the management of this stove there are certain precautions to be observed at first with attention,



attention, till they become habitual. To avoid the inconvenience of smoke, see that the grate *H* be clear before you begin to light a fresh fire. If you find it clogged with cinders and ashes, turn it up with your tongs, and let them fall upon the grate below; the ashes will go through it, and the cinders may be raked off, and returned into the vase, when you would burn them. Then see that all the sliding plates are in their places, and close shut, that no air may enter the stove but through the round opening at the top of the vase. And, to avoid the inconvenience of dust from the ashes, let the ash-drawer be taken out of the room to be emptied; and when you rake the passages, do it when the draft of the air is strong inwards, and put the ashes carefully into the ash-box, that remaining in its place.

If, being about to go abroad, you would prevent your fire burning in your absence, you may do it by taking the brass flame from the top of the vase, and covering the passage with a round tin plate, which will prevent the entry of more air than barely sufficient to keep a few of the coals alive. When you return, though some hours absent, by taking off the tin plate, and admitting the air, your fire will soon be recovered.

The effect of this machine, well managed, is to burn not only the coals, but all the smoke of the coals; so that while the fire is burning, if you go out and observe the top of your chim-



ney, you will see no smoke issuing, nor any thing but clear warm air, which, as usual, makes the bodies seen through it appear waving.

But let none imagine from this, that it may be a cure for bad or smoky chimneys, much less that, as it burns the smoke, it may be used in a room that has no chimney. It is by the help of a good chimney, the higher the better, that it produces its effect; and though a flue of plate iron sufficiently high might be raised in a very lofty room, the management to prevent all disagreeable vapour would be too nice for common practice, and small errors would have unpleasing consequences.

It is certain that clean iron yields no offensive smell when heated. Whatever of that kind you perceive, where there are iron stoves, proceeds therefore from some foulness burning or fuming on their surface. They should therefore never be spit upon, or greased, nor should any dust be suffered to lie upon them. But as the greatest care will not always prevent these things, it is well once a week to wash the stove with soap lees and a brush, rinsing it with clean water.

### *The Advantages of this Stove.*

1. The chimney does not grow foul, nor ever need sweeping; for as no smoke enters it, no soot can form in it.

2. The air heated over common fires instantly quits the room, and goes up the chimney

ney with the smoke; but in the stove, it is obliged to descend in flame, and pass through the long winding horizontal passages, communicating its heat to a body of iron plate, which having thus time to receive the heat, communicates the same to the air of the room, and thereby warms it to a greater degree.

3. The whole of the fuel is consumed by being turned into flame, and you have the benefit of its heat; whereas in common chimneys a great part goes away in smoke, which you see as it rises, but it affords you no rays of warmth. One may obtain some notion of the quantity of fuel thus wasted in smoke, by reflecting on the quantity of soot that a few weeks firing will lodge against the sides of the chimney, and yet this is formed only of those particles of the column of smoke that happen to touch the sides in its ascent. How much more must have passed off in the air? And we know that this soot is still fuel; for it will burn and flame as such, and when hard caked together, is indeed very like, and almost as solid as the coal it proceeds from. The destruction of your fuel goes on nearly in the same quantity whether in smoke or in flame: but there is no comparison in the difference of heat given. Observe when fresh coals are first put on your fire, what a body of smoke arises. This smoke is for a long time too cold to take flame. If you then plunge a burning candle into it, the candle, instead of inflaming the smoke, will instantly be itself extinguished. Smoke must have a certain degree of heat to be

inflammable. As soon as it has acquired that degree, the approach of a candle will inflame the whole body, and you will be very sensible of the difference of the heat it gives. A still easier experiment may be made with the candle itself. Hold your hand near the side of its flame, and observe the heat it gives; then blow it out, the hand remaining in the same place, and observe what heat may be given by the smoke that rises from the still burning snuff. You will find it very little. And yet that smoke has in it the substance of so much flame, and will instantly produce it, if you hold another candle above it so as to kindle it. Now the smoke from the fresh coals laid on this stove, instead of ascending and leaving the fire while too cold to burn, being obliged to descend through the burning coals, receives among them that degree of heat which converts it into flame, and the heat of that flame is communicated to the air of the room, as above explained.

4. The flame from the fresh coals laid on in this stove, descending through the coals already ignited, preserves them long from consuming, and continues them in the state of red coals as long as the flame continues that surrounds them; by which means the fires made in this stove are of much longer duration than in any other, and fewer coals are therefore necessary for a day. This is a very material advantage indeed. That flame should be a kind of pickle to preserve burning coals from consuming,

fuming, may seem a paradox to many, and very unlikely to be true, as it appeared to me the first time I observed the fact. I must therefore relate the circumstances, and shall mention an easy experiment, by which my reader may be in possession of every thing necessary to the understanding of it. In the first trial I made of this kind of stove, which was constructed of thin plate iron, I had instead of the vase a kind of inverted pyramid, like a mill-hopper; and fearing at first that the small grate contained in it might be clogged by cinders, and the passage of the flame sometimes obstructed, I ordered a little door near the grate, by means of which I might on occasion clear it; though after the stove was made, and before I tried it, I began to think this precaution superfluous, from an imagination, that the flame being contracted in the narrow part where the grate was placed, would be more powerful in consuming what it should there meet with, and that any cinders between or near the bars would be presently destroyed, and the passage opened. After the stove was fixed and in action, I had a pleasure now and then in opening that door a little, to see through the crevice how the flame descended among the red coals; and observing once a single coal lodged on the bars in the middle of the focus, a fancy took me to observe by my watch in how short a time it would be consumed. I looked at it long without perceiving it to be at all diminished, which surprised me greatly. At length it occurred to  
me,



me, that I and many others had seen the same thing thousands of times, in the conservation of the red coal formed in the snuff of a burning candle, which, while enveloped in flame, and thereby prevented from the contact of passing air, is long continued, and augments instead of diminishing, so that we are often obliged to remove it by the snuffers, or bend it out of the flame into the air, where it consumes presently to ashes. I then supposed, that to consume a body by fire, passing air was necessary to receive and carry off the separated particles of the body; and that the air passing in the flame of my stove, and in the flame of a candle, being already saturated with such particles, could not receive more, and therefore left the coal undiminished as long as the outward air was prevented from coming to it by the surrounding flame, which kept it in a situation somewhat like that of charcoal in a well luted crucible, which, though long kept in a strong fire, comes out unconsumed.

An easy experiment will satisfy any one of this conserving power of flame enveloping red coal. Take a small stick of deal, or other wood, the size of a goose quill, and hold it horizontally and steadily in the flame of the candle above the wick, without touching it, but in the body of the flame. The wood will first be inflamed, and burn beyond the edge of the flame of the candle, perhaps a quarter of an inch. When the flame of the wood goes out, it will leave a red coal at the end of the stick,  
part



part of which will be in the flame of the candle and part out in the air. In a minute or two you will perceive the coal in the air diminish gradually, so as to form a neck; while the part in the flame continues of its first size, and at length the neck being quite consumed, it drops off; and by rolling it between your fingers when extinguished, you will find it still a solid coal.

However, as one cannot be always putting on fresh fuel in this stove to furnish a continual flame, as is done in a candle, the air in the intervals of time gets at the red coals, and consumes them. Yet the conservation, while it lasted, so much delayed the consumption of the coals, that two fires, one made in the morning, and the other in the afternoon, each made by only a hatful of coals, were sufficient to keep my writing-room, about sixteen feet square and ten high, warm a whole day. The fire kindled at seven in the morning would burn till noon; and all the iron of the machine, with the walls of the niche, being thereby heated, the room kept warm till evening, when another smaller fire kindled kept it warm till midnight.

Instead of the sliding plate *E*, which shuts the front of the box *C*, I sometimes used another, which had a pane of glass, or, which is better, of Muscovy talc, that the flame might be seen descending from the bottom of the vase, and passing in a column through the box *C*, into the cavities of the bottom plate, like water falling from a funnel, admirable to such as  
are

are not acquainted with the nature of the machine, and in itself a pleasing spectacle.

Every utensil, however properly contrived to serve its purpose, requires some practice before it can be used adroitly. Put into the hands of a man, for the first time, a gimblet or a hammer (very simple instruments), and tell him the use of them, he shall neither bore a hole nor drive a nail with the dexterity or success of another, who has been a little accustomed to handle them. The beginner therefore in the use of this machine, will do well not to be discouraged with little accidents that may arise at first from his want of experience. Being somewhat complex, it requires, as already said, a variety of attentions; habit will render them unnecessary; and the studious man who is much in his chamber, and has a pleasure in managing his own fire, will soon find this a machine most comfortable and delightful. To others who leave their fires to the care of ignorant servants, I do not recommend it. They will with difficulty acquire the knowledge necessary, and will make frequent blunders that will fill your room with smoke. It is therefore by no means fit for common use in families. It may be advisable to begin with the flaming kind of stone coal, which is large, and, not caking together, is not so apt to clog the grate. After some experience, any kind of coal may be used, and with this advantage, that no smell, even from the most sulphureous kind, can come into your room, the current of air being constantly

stantly into the vase, where too that smell is all consumed.

The vase form was chosen as being elegant in itself, and very proper for burning of coals: where wood is the usual fuel, and must be burnt in pieces of some length, a long square chest may be substituted, in which *A* is the cover opening by a hinge behind, *B* the grate, *C* the hearth-box with its divisions as in the other, *D* the plate or cover of the plan of the top of the chest, *E* the long narrow grate\*. This I have not tried, but the vase machine was completed in 1771, and used by me in London three winters, and one afterwards in America, much to my satisfaction; and I have not yet thought of any improvement it may be capable of, though such may occur to others. For common use, while in France, I have contrived another grate for coals, which has in part the same property of burning the smoke, and preserving the red coals longer by the flame, though not so completely as in the vase, yet sufficiently to be very useful, which I shall now describe as follows:

*A* is a round grate, one foot (French) in diameter, and eight inches deep between the bars and the back; the sides and back of plate iron; the sides having holes of half an inch diameter, distant three or four inches from each other, to let in air for enlivening the fire†. The back without holes. The sides do not meet at top

\* Plate II. Figure 17.

† Plate II. Fig. 18.

nor at bottom by eight inches : that square is filled by grates of small bars crossing front to back to let in air below, and let out the smoke or flame above. The three middle bars of the front grate are fixed ; the upper and lower may be taken out and put in at pleasure, when hot, with a pair of pincers. This round grate turns upon an axis, supported by the crotchet *B*, the stem of which is an inverted conical tube five inches deep, which comes on as many inches upon a pin that fits it, and which is fixed upright in a cast iron plate *D*, that lies upon the hearth ; in the middle of the top and bottom grates are fixed small upright pieces *E E*, about an inch high, which, as the whole is turned on its axis, stop it when the grate is perpendicular. Figure 19 is another view of the same machine.

In making the first fire in a morning with this grate, there is nothing particular to be observed. It is made as in other grates, the coals being put in above, after taking out the upper bar, and replacing it when they are in. The round figure of the fire when thoroughly kindled is agreeable ; it represents the great giver of warmth to our system. As it burns down and leaves a vacancy above, which you would fill with fresh coals, the upper bar is to be taken out, and afterwards replaced. The fresh coals, while the grate continues in the same position, will throw up, as usual, a body of thick smoke. But every one accustomed to coal fires in common grates, must have observed,



served, that pieces of fresh coal stuck in below among the red coals, have their smoke so heated, as that it becomes flame as fast as it is produced, which flame rises among the coals, and enlivens the appearance of the fire. Here then is the use of this swivel grate. By a push with your tongs or poker, you turn it on its pin till it faces the back of the chimney, then turn it over on its axis gently till it again faces the room, whereby all the fresh coals will be found under the live coals, and the greater part of the smoke arising from the fresh coals will in its passage through the live ones be heated, so as to be converted into flame: whence you have much more heat from them, and your red coals are longer preserved from consuming. I conceive this construction, though not so complete a consumer of all the smoke as the vase, yet to be fitter for common use, and very advantageous. It gives too a full sight of the fire, always a pleasing object, which we have not in the other. It may with a touch be turned more or less from any one of the company that desires to have less of its heat, or presented full to one just come out of the cold. And supported in a horizontal position, a tea-kettle may be boiled on it.

The author's description of his Pennsylvania fire-place, first published in 1744, having fallen into the hands of workmen in Europe, who did not, it seems, well comprehend the principles of that machine, it was much disfigured in their imitations of it; and one of its main intentions,



tentions, that of admitting a sufficient quantity of fresh air warmed in entering through the air-box, nearly defeated, by a pretended improvement, in lessening its passages to make more room for coals in a grate. On pretence of such improvements, they obtained patents for the invention, and for a while made great profit by the sale, till the public became sensible of that defect in the expected operation. If the same thing should be attempted with this vase stove, it will be well for the buyer to examine thoroughly such pretended improvements, lest, being the mere productions of ignorance, they diminish or defeat the advantages of the machine, and produce inconvenience and disappointment.

The method of burning smoke, by obliging it to descend through hot coals, may be of great use in heating the walls of a hot-house. In the common way, the horizontal passages or flues that are made to go and return in those walls, lose a great deal of their effect when they come to be foul with soot; for a thick blanket-like lining of soot prevents much of the hot air from touching and heating the brick-work in its passage, so that more fire must be made as the flue grows fouler: but by burning the smoke they are kept always clean. The same method may also be of great advantage to those businesses in which large coppers or caldrons are to be heated.

*Written at Sea, 1785.*

F I N I S.

